CLAIMS:

1. A method for processing a layer containing a high-permittivity material, the method comprising:

etching a layer containing a high-permittivity material by exposing the layer to a process gas comprising a β-diketone etch reactant.

2. The method according to claim 1, wherein the layer containing a high permittivity material overlies another layer in a substrate.

3. The method according to claim 2, further comprising providing the substrate in a process chamber.

4. The method according to claim 1, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

5. The method according to claim 4, wherein the β-diketone includes hfacH.

6. The method according to claim 1, wherein the process gas further comprises an inert gas.

7. The method according to claim 6, wherein the inert gas comprises at least one of Ar, He, Ne, Kr, Xe, and N_2.

8. The method according to claim 1, wherein the process gas further comprises an oxygen-containing gas.

9. The method according to claim 8, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

10. The method according to claim 3, further comprising maintaining the substrate at a temperature of less than 400° C.

11. The method according to claim 3, further comprising maintaining the substrate at a temperature of less than 200° C.

12. The method according to claim 1, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

13. The method according to claim 12, wherein the high-permittivity material comprises HfO_2.

14. The method according to claim 1, further comprising maintaining a flow rate of the process gas at less than 2000 sccm.

15. The method according to claim 1, wherein the process gas further comprises a carrier gas.

16. The method according to claim 15, wherein the carrier gas comprises an inert gas.

17. The method according to claim 16, wherein the inert gas comprises at least one of Ar, He, and N_2.

18. The method according to claim 15, further comprising maintaining a flow rate of the β-diketone-containing carrier gas at less than 1000 sccm.

19. The method according to claim 1, further comprising maintaining a flow rate of the β-diketone at less than 1000 sccm.

20.The method according to claim 3, further comprising maintaining a pressure in the process chamber at less than about 10 Torr.

21.A processing system for processing a layer containing a high-permittivity material, comprising:

a process chamber;

a gas injection system configured to inject a process gas into the process chamber, wherein the process gas comprises a β-diketone etch reactant;

a substrate holder, upon which a substrate with the layer containing the high-permittivity material resides; and

a controller coupled to the process chamber and the gas injection system and configured to control the process chamber and the gas injection system.

22.The system according to claim 21, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

23.The system according to claim 22, wherein the β-diketone can be hfacH.

24.The system according to claim 21, wherein the process gas further comprises an inert gas.

25.The system according to claim 24, wherein the inert gas comprises at least one of Ar, He, Ne, Kr, Xe, and N_2.

26.The system according to claim 21, wherein the process gas further comprises an oxygen-containing gas.

27.The system according to claim 26, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

28. The system according to claim 21, wherein the substrate holder is configured to maintain the substrate temperature at less than about 400° C.

29. The system according to claim 21, wherein the substrate holder is configured to maintain the substrate temperature at less than about 200° C.

30. The system according to claim 21, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

31. The system according to claim 30, wherein high-permittivity material comprises HfO_2.

32. The system according to claim 21, wherein a flow rate of the process gas is less than 2000 sccm.

33. The system according to claim 21, wherein the process gas further comprises a carrier gas.

34. The system according to claim 33, wherein the carrier gas comprises an inert gas.

35. The system according to claim 34, wherein the inert gas comprises at least one of Ar, He, and N_2.

36. The system according to claim 33, wherein a flow rate of the β-diketone-containing carrier gas is less than 1000 sccm.

37. The system according to claim 21, wherein a flow rate of the β-diketone is less than 1000 sccm.

38. The system according to claim 21, wherein a pressure in the process chamber is less than about 10 Torr.

39. A method of processing a layer containing a high-permittivity material, the method comprising:

etching a layer containing the high-permittivity material by exposing the layer to an etch reactant and a hyperthermal beam of neutral atoms.

40. The method according to claim 39, wherein the layer containing a high-permittivity material overlies another layer in a substrate.

41. The method according to claim 40, further comprising providing the substrate in a process chamber.

42. The method according to claim 39, wherein the etching further comprises:

introducing a process gas into a process chamber comprising the etch reactant; and

introducing a hyperthermal beam of neutral atoms into the process chamber.

43. The method according to claim 39, wherein the etch reactant comprises a β-diketone.

44. The method according to claim 43, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

45. The method according to claim 44, wherein the β-diketone comprises hfacH.

46. The method according to claim 42, wherein the etch reactant comprises a β-diketone.

47. The method according to claim 46, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

48. The method according to claim 47, wherein the β-diketone comprises hfacH.

49. The method according to claim 42, wherein the process gas further comprises an inert gas.

50. The method according to claim 49, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, and N_2, or mixtures thereof.

51. The method according to claim 42, wherein the process gas further comprises an oxygen-containing gas.

52. The method according to claim 51, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

53. The method according to claim 39, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

54. The method according to claim 53, wherein the high-permittivity material comprises HfO_2.

55. The method according to claim 40, further comprising maintaining the substrate temperature at less than about 400° C.

56. The method according to claim 40, further comprising maintaining the substrate temperature at less than about 200° C.

57. The method according to claim 39, wherein the hyperthermal beam of neutral atoms comprises at least one of He, Ar, O, and N.

58. The method according to claim 39, wherein the layer is at least initially exposed to the etch reactant before initiation of exposure to the hyperthermal beam of neutral atoms.

59. A method of processing a layer containing a high-permittivity material, the method comprising:

modifying a layer containing a high-permittivity material by exposing the layer to a hyperthermal beam of neutral atoms; and

etching the modified high-permittivity layer by reacting an etch reactant with the modified high-permittivity layer.

60. The method according to claim 59, wherein the layer containing a high-permittivity material overlies another layer in a substrate.

61. The method according to claim 60, further comprising providing the substrate in a process chamber.

62. The method according to claim 59, wherein the etching further comprises:

introducing a process gas comprising the etch reactant into a process chamber; and

introducing a hyperthermal beam of neutral atoms into the process chamber.

63. The method according to claim 59, wherein the etch reactant comprises a β-diketone.

64. The method according to claim 63, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

65. The method according to claim 64, wherein the β-diketone comprises hfacH.

66. The method according to claim 62, wherein the process gas further comprises an inert gas.

67. The method according to claim 66, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, and N_2, or mixtures thereof.

68. The method according to claim 62, wherein the process gas further comprises an oxygen-containing gas.

69. The method according to claim 68, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

70. The method according to claim 59, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

71. The method according to claim 70, wherein the high-permittivity material comprises HfO_2.

72. The method according to claim 60, wherein the substrate temperature is less than about 400° C.

73. The method according to claim 60, wherein the substrate temperature is less than about 200° C.

74. The method according to claim 59, wherein the hyperthermal beam of neutral atoms comprises at least one of He, Ar, O, and N.

75. A method of processing a layer containing a high-permittivity material, the method comprising:

removing a layer containing a high-permittivity material by exposing the layer to a hyperthermal beam of neutral atoms.

76. The method according to claim 75, wherein the layer containing a high-permittivity material overlies another layer in a substrate.

77. The method according to claim 75, further comprising providing the substrate in a process chamber.

78. The method according to claim 75, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

79. The method according to claim 78, wherein the high-permittivity material comprises HfO_2.

80. The method according to claim 75, wherein the hyperthermal beam of neutral atoms comprises at least one of He, Ar, O, and N.

81. A processing system comprising:

a process chamber;

a source for a hyperthermal beam of neutral atoms;

a substrate holder configured to expose a substrate comprising a layer of high-permittivity material to the hyperthermal beam of neutral atoms; and

a controller that controls the processing system.

82. The system according to claim 81, further comprising a gas injection system configured to inject a process gas comprising an etch reactant into the process chamber.

83. The system according to claim 82, wherein the etch reactant comprises a β-diketone.

84. The system according to claim 83, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

85. The system according to claim 84, wherein the β-diketone comprises hfacH.

86. The system according to claim 82, wherein the process gas further comprises an inert gas.

87. The system according to claim 86, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, and N_2, or mixtures thereof.

88. The system according to claim 82, wherein the process gas further comprises an oxygen-containing gas.

89. The system according to claim 88, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

90. The system according to claim 81, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

91. The system according to claim 90, wherein the high-permittivity material comprises HfO_2.

92. The system according to claim 81, wherein the hyperthermal beam of neutral atoms comprises at least one of He, Ar, O, and N.

93. A method of processing a layer containing a high-permittivity material, the method comprising:

modifying a layer containing a high-permittivity material by exposing the layer to a first process gas in a plasma; and

etching the modified high-permittivity layer in the absence of a plasma by exposing the layer to a second process gas comprising an etch reactant.

94. The method according to claim 93, wherein the layer containing a high-permittivity material overlies another layer in a substrate.

95. The method according to claim 94, further comprising providing the substrate in a process chamber.

96. The method as claimed in claim 93, wherein the modifying step partially removes the layer containing the high-permittivity material.

97. The method as claimed in claim 93, wherein the modifying step partially disassociates the layer containing the high-permittivity material.

98. The method according to claim 93, wherein the first process gas comprises a reactive gas.

99. The method according to claim 96, wherein the reactive gas comprises at least one of HBr and HCl.

100. The method according to claim 98, wherein the first process gas further comprises an inert gas.

101. The method according to claim 100, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, and N_2, or mixtures thereof.

102. The method according to claim 93, wherein the first process gas comprises an inert gas.

103. The method according to claim 102, wherein the inert gas comprises at least one of He, Ne, Ar, Kr, Xe, and N_2.

104. The method according to claim 93, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.

105. The method according to claim 104, wherein the high-permittivity material comprises HfO_2.

106. The method according to claim 93, wherein the etch reactant comprises a β-diketone.

107. The method according to claim 106, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

108. The method according to claim 107, wherein the β-diketone comprises hfacH.

109. The method according to claim 93, wherein the second process gas further comprises an inert gas.

110. The method according to claim 109, wherein the inert gas comprises at least one of He, Ne, Ar, Kr, Xe, and N_2.

111. The method according to claim 93, wherein the second process gas further comprises an oxygen-containing gas.

112. The method according to claim 111, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

113. The method according to claim 95, further comprising modifying the substrate temperature at less than about 400° C.

114. The method according to claim 95, further comprising modifying the substrate temperature at less than about 200° C.

115. The method according to claim 93, wherein the modifying and the etching are carried out in the same process chamber.

116. The method according to claims 93, wherein the modifying and the etching are carried out in different process chambers.

117. The method according to claim 93, further comprising modifying a flow rate of the second process gas at less than 2000 sccm.

118. The method according to claim 106, further comprising modifying a flow rate of a β-diketone-containing carrier gas at less than 1000 sccm.

119. The method according to claim 93, further comprising modifying a flow rate of the etch reactant at less than 1000 sccm.

120. A processing system comprising:

a chamber comprising means for operating as a plasma processing chamber and means for operating as an etching chamber;

a gas injection system configured to inject a first process gas into the chamber when the chamber is operating as a plasma processing chamber and configured to inject a second process gas into the chamber when the chamber is operating as an etching chamber;

a plasma source configured to create a plasma in the chamber using said first process gas when the chamber is operating as a plasma processing chamber;

a substrate holder configured to expose a substrate comprising a layer of high-permittivity material to the plasma when the chamber is operating as a plasma processing chamber, thereby creating a modified layer and configured to expose a substrate comprising the modified layer of high-permittivity material to the second process gas comprising an etch reactant when the chamber is operating as an etching chamber; and

a controller configured to control said chamber, said gas injection system, said plasma source, and said substrate holder.

121. The system according to claim 120, wherein the etch reactant comprises a β-diketone.

122. The system according to claim 121, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

123. The system according to claim 122, wherein the β-diketone comprises hfacH.

124. A processing system comprising:

a plasma processing chamber;

a gas injection system configured to inject a first process gas into the plasma processing chamber;

a plasma source configured to create a plasma in the plasma processing chamber using the first process gas;

a first substrate holder configured to expose a substrate comprising a layer of high-permittivity materials to the plasma, thereby creating a modified layer;

an etching chamber operatively coupled to the plasma processing chamber and said gas injection system, the gas injection

system being configured to inject a second process gas into the etching chamber;

a second substrate holder configured to expose a substrate comprising the modified layer of high-permittivity material to the second process gas comprising an etch reactant; and

a controller configured to control the plasma processing chamber, the gas injection system, and the etching chamber.

125. The system according to claim 124, wherein the plasma processing chamber is operatively coupled to the etching chamber by a transfer system.

126. The system according to claim 124, wherein plasma processing chamber is disposed in the process chamber.

127. The system according to claim 124, wherein the plasma source comprises an inductive coil.

128. The system according to claim 124, wherein the plasma source comprises a plate electrode.

129. The system according to claim 124, wherein the plasma source comprises an antenna.

130. The system according to claim 124, wherein the plasma source comprises an ECR source.

131. The system according to claim 124, wherein the plasma source comprises a Helicon wave source.

132. The system according to claim 124, wherein the plasma source comprises a surface wave source.

133. The system according to claim 124, wherein the first process gas comprises a reactive gas.

134. The system according to claim 133, wherein the reactive gas comprises at least one of HBr and HCl.

135. The system according to claim 124, wherein the first process gas comprises an inert gas.

136. The system according to claim 135, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, N_2, or mixtures thereof.

137. The system according to claim 124, wherein the second process gas comprises an inert gas.

138. The system according to claim 137, wherein the inert gas is selected from He, Ne, Ar, Kr, Xe, N_2, or mixtures thereof.

139. The system according to claim 124, wherein the etch reactant comprises a β-diketone.

140. The system according to claim 139, wherein the β-diketone comprises at least one of acacH, tfacH, and hfacH.

141. The system according to claim 124, wherein the second process gas further comprises an oxygen-containing gas.

142. The system according to claim 141, wherein the oxygen-containing gas comprises at least one of O_2, H_2O, and H_2O_2.

143. The system according to claim 124, wherein the high-permittivity material comprises at least one of Ta_2O_5, TiO_2, ZrO_2, Al_2O_3, HfSiO, and HfO_2.